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WELD REPAIRING OF A NICKEL-ALUMINUM BRONZE VALVE CASTING

by
PHYSICAL METALLURGY SECTION

MINERALS RESEARCH PROGRAM
PHYSICAL METALLURGY RESEARCH LABORATORIES
DIVISION REPORT MRP/PMRL 84-33(TR)

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ABSTRACT

A Ni-Al bronze valve casting conforming to BS1400-AB2 specification has been weld repaired with Ni-Al bronze filler wire of low aluminum content (~8.5%). It is shown that the γ_2 phase which forms in the fusion zone and heat-affected zone can be eliminated by the post-weld heat treatment at 700°C.

LABORATOIRES DE RECHERCHE EN MÉTALLURGIE PHYSIQUE
RAPPORT MRP/PMRL 84-33(TR)

REMISE EN ÉTAT PAR SOUDAGE D'UNE VALVE COULÉE EN CUPRO-ALUMINIUM AU NICKEL

par

M. Sahoo

RÉSUMÉ

On a réparé par soudage une valve coulée au cupro-aluminium au nickel se conformant à la norme BS1400-AB2. Pour ce faire, on s'est servi d'un fil d'apport à faible teneur en aluminium (~8,5 %). L'auteur démontre qu'un traitement thermique effectué à une température de 700°C après le soudage a pour effet d'éliminer la phase γ_2 qui se forme dans les zones de fusion et de transformation.

INTRODUCTION

At present, the Canadian Armed Forces (Navy) uses nickel-aluminum bronze (NAB) valve castings (conforming to BS1400-AB2) for ships and submarines. The composition ranges of this specification are given in Table 1 together with the composition ranges for ASTM B148 alloy C95800. In previous studies [1-3] at the Physical Metallurgy Research Laboratories (PMRL), the microstructures and mechanical properties of sand-cast, and cast and metal-inert-gas (MIG) welded NAB alloys have been examined in detail. As a result of this work, it was recommended that commercial castings should be produced at the low end of the aluminum range and welded or weld-repaired with filler wire of matching composition. A post-weld or corrosion inhibiting heat treatment (6h at 700°C followed by air cooling), can then be employed to remove the deleterious γ_2 phase from the fusion zone and the heat-affected zone (HAZ), and to improve the sea water corrosion resistance and mechanical properties of the casting.

Following the above recommendations, the Defence Research Establishment Atlantic (DREA) asked to have a NAB valve casting weld-repaired with a filler wire of low aluminum content for subsequent metallographic examination. To this end, the casting shown in Fig. 1 was supplied to PMRL.

EXPERIMENTAL PROCEDURE

Weld repairing was done in the flange and body at Canadian Stone Marine Ltd., Iberville, Quebec, using two types of NAB filler wires. The compositions are given in Table 1. The Ampcotrode 46 filler wire was used in the weldability studies of NAB alloys at PMRL (3). The Nartrode E filler wire is usually used by Canadian Stone Marine Ltd. for weld repairing of propellers and is purchased from Ashtons, U.K. The parameters for weld repairing of the NAB valve casting are:

Method	: MIG (Metal-Inert-Gas welding)
Voltage	: 31 V
Current	: 400 A
Wire speed	: 710 cm/min
Shielding gas	: Argon, 1.4 m^3/min

The thickness of the body and the flange were respectively 11 and 25 mm. The area to be weld repaired was drilled to a depth of 6 to 7 mm and then ground to produce a smooth surface.

The weld-repaired areas were radiographed for defects and then sectioned for post-weld heat treatment (6h at 700°C and then air cooled) and metallographic examination in the as-welded and post-weld heat treated conditions.

RESULTS AND DISCUSSION

COMPOSITIONS

Chemical composition of the valve casting, determined by wet chemical analysis, is given in Table 1. It is evident that its composition conforms to the old BS1400-AB2 specification and that the aluminum, nickel and iron contents are higher than those specified in ASTM B148 for alloy C95800.

The nickel content of the Ampcotrode 46 filler wire is higher than that of Nartrode E whereas, the reverse is true of the aluminum content. The aluminum content of the filler wire plays an important role in the weld repairing of NAB alloys by controlling the volume fraction of deleterious γ_2 phase in the fusion and heat-affected zones. The aluminum content should be close to 8.5% to optimize impact toughness in the welds (3).

X-RAY EXAMINATION

Radiography of the casting showed it to be fairly sound. There was some shrinkage porosity in the body as shown in Fig. 1 but the weld-repaired areas appeared to be sound except for a couple of pores in the flanges.

METALLOGRAPHIC EXAMINATION

Optical micrographs of the weld-repaired section for the Nartrode E and the Ampcotrode 46 filler wires are shown in Figs. 2(a) and (b) respectively. The fusion zone and heat-affected zone microstructures for both the filler wires were found to be similar. No HAZ cracking was observed in either case.

Optical micrographs of the base metal, fusion line, fusion zone and heat-affected zones are given in Fig. 3(a) to (e) for the Ampcotrode 46 filler

wire. Scanning electron micrographs of the weldments are shown in Figs. 4(a) to (c). The base-metal microstructure [(Fig. 3(a) and 4(a)] is characterized by the white α-matrix, spherical and rosette-shaped iron-rich kappa phases, lamellar nickel-rich kappa phases and the dark etching γ_2 phases. The martensitic structure of the fusion zone is evident from Fig. 3(c) and 4(b). In addition to the high volume fraction of the γ_2 phase, very fine iron-rich and nickel-rich kappa phases can be seen in the scanning electron micrographs. Because the HAZ gets heated to high temperatures (900 - 1000°C) during weld-repairing, fast cooling produces a martensitic structure near the fusion line [Fig. 3(d) and 4(c)]. Very fine kappa phases, large rosette-shaped iron-rich kappa phases, and the dark etching γ_2 phase are also features of this HAZ microstructure. The acicularity of the HAZ microstructure decreases away from the fusion line. However, a lot of γ_2 phase is still present in the HAZ.

The microstructural changes that took place after the post-weld heat treatment (corrosion-inhibiting heat treatment) of 6h at 700°C followed by air cooling were studied by both optical and scanning electron microscopy and are depicted in Fig. 5(a) to (c) and 6(a) to (c) respectively. It is evident that the γ_2 phase is eliminated from the base metal, HAZ and fusion zones during the post-weld heat treatment. In addition, fine kappa phases were precipitated in the α-matrix in all cases. However the other microstructural features of the base metal remained unchanged.

It should be noted that the valve body contained one weld-repaired area in the as-received condition. Metallographic examination indicated that weld-repairing had been done with a nickel-free high aluminum filler similar to Ampcotrode 10 (3). Microstructures of such weldments have been described in detail in earlier reports (3,4). The results of PMRL work show that weld repairing with such high aluminum nickel free filler wires is not desirable (3).

CONCLUSIONS

1. A Ni-Al bronze valve casting has been weld-repaired in a number of areas with Ni-Al bronze filler wires (Ampcotrode 46 and Nartrode E) of low aluminum content (~8.5%) and sound welds were obtained.
2. Deleterious γ_2 phase is formed in the fusion zone and HAZ during welding.

3. A post-weld heat treatment of 6h at 700°C is effective in eliminating the γ_2 phase from the base metal, HAZ and fusion zone. In addition, a fine kappa phase precipitate is formed in the α-matrix.

ACKNOWLEDGEMENTS

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3. Sahoo, M. "Weldability of nickel-aluminum bronze alloy C95800"; AFS Transactions, vol. 90, p. 893 (1982).
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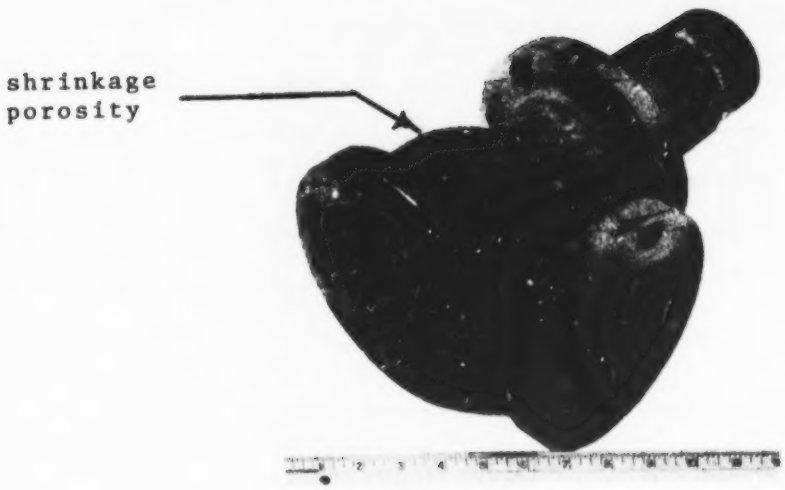
Table 1 - Chemical composition (wt %) of the Ni-Al bronze valve casting and the filler wires

Material	Cu	Al	Ni	Fe	Mn	Si	Pb
Valve	78.84	9.93	5.43	4.65	0.90	0.21	0.027
Ampcotrode 46	81.00	8.23	5.08	4.11	0.90	-	-
Nartrode E	Bal.	8.86	4.30	4.20	1.06	0.005	-
BS1400-AB2 or DG ships 8520 (old)	Bal.	8.8-10.0	4.0-* 5.5	4.0-5.5	1.5 max	0.1	0.02
BS1400-AB2 or DG ships 8520 (new)	Bal.	8.8-9.5	4.5-* 5.5	4.0-5.5	0.75 1.3	0.1	0.02
ASTM B148 (alloy C95800)	79 min	8.5-9.5	4.0-5.0	3.5-4.5	0.8-1.5	0.1 max	0.03 max

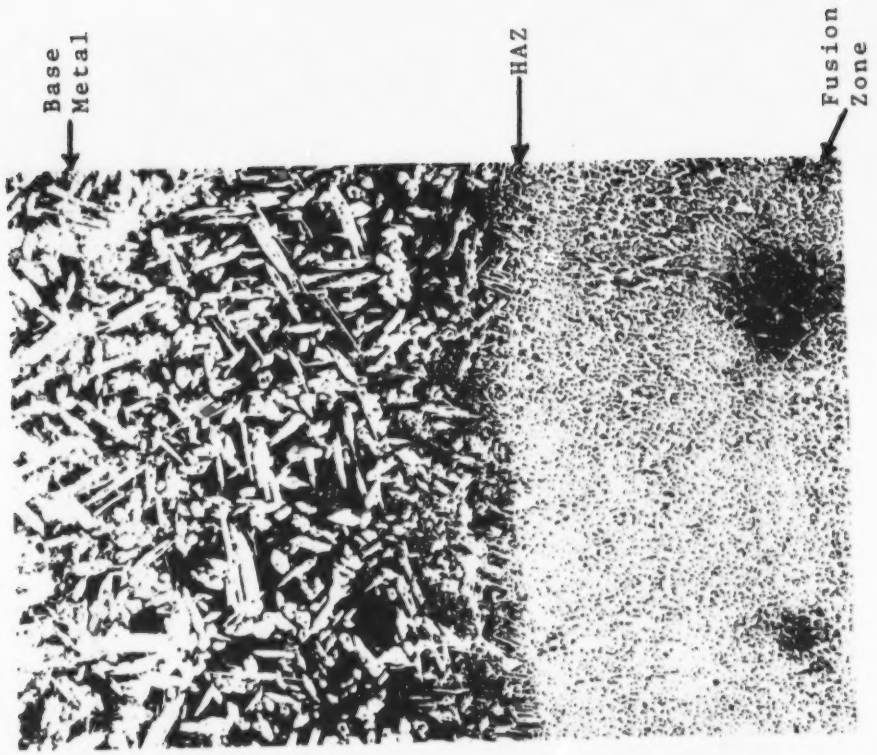
* Ni > Fe



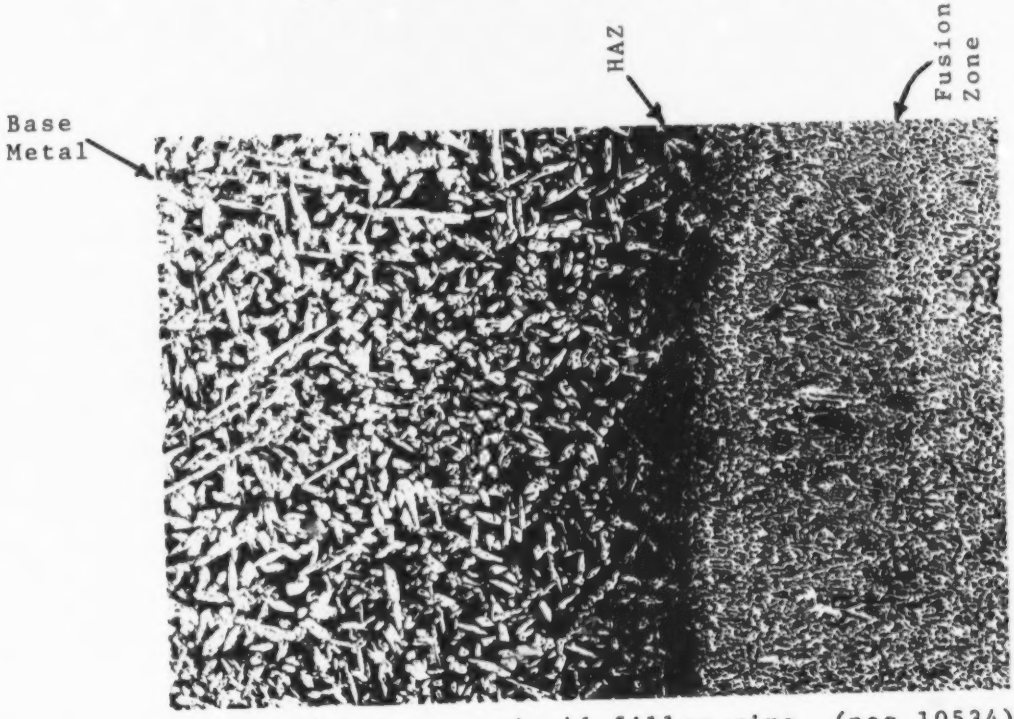
(neg 6868)

(neg 6869)

Fig. 1. Nickel-aluminum bronze valve casting received from DREA, Halifax. The flange from the threaded part has been removed.



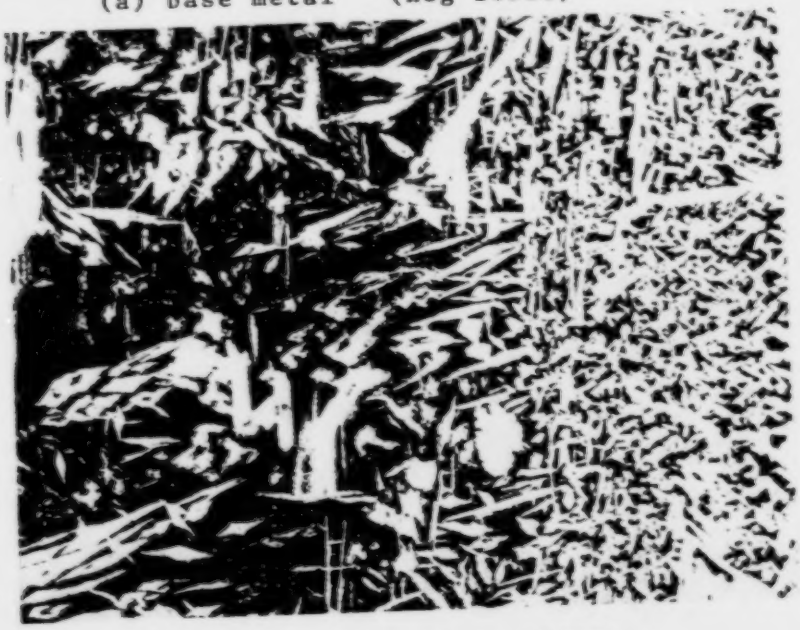
(a) Nartrode E filler wire (neg 10535)



(b) Ampcotrode 46 filler wire (neg 10534)

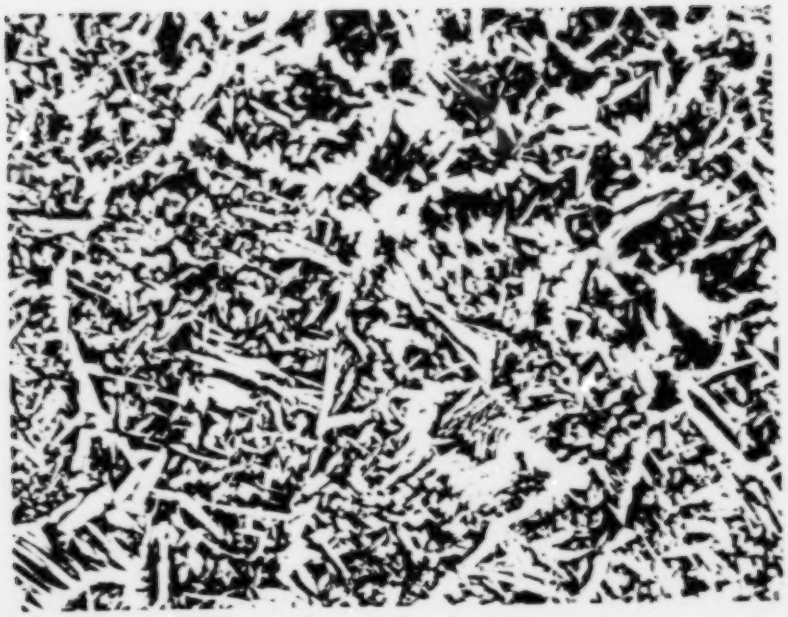
Fig. 2. Optical micrograph of weldments for various filler wires. Alcoholic ferric chloride, etch. X100

(a) base metal (neg 10533)



(b) Fusion line (neg 10532)

Fig. 3. cont'd.



(c) Fusion zone (neg 10531)

(d) HAZ near fusion line (neg 10530)

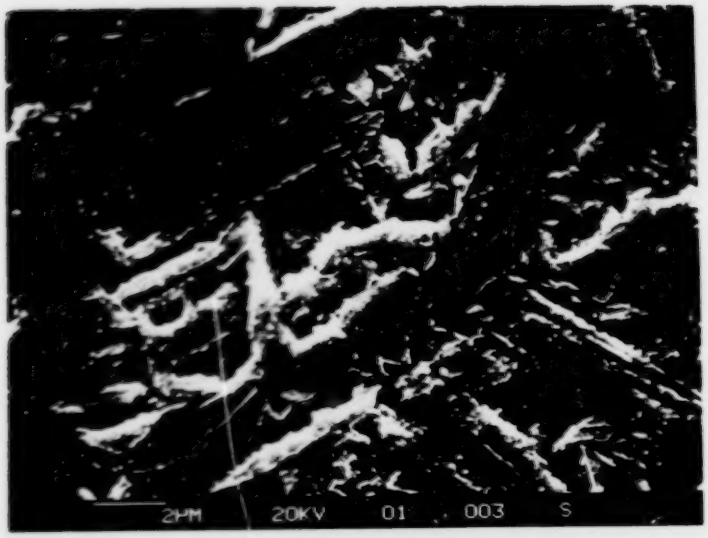
Fig. 3. cont'd.

(e) HAZ away from fusion line (neg 10529)

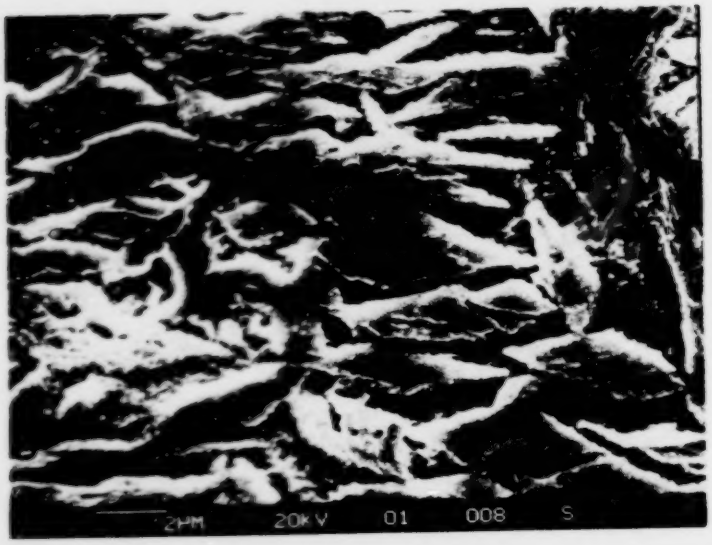
Fig. 3. Optical micrographs of weld-repaired area. Amcotrode 46 filler wire. Alcoholic ferric chloride etch. X1000

(a) base metal (neg 10477)

Fig. 4. cont'd.

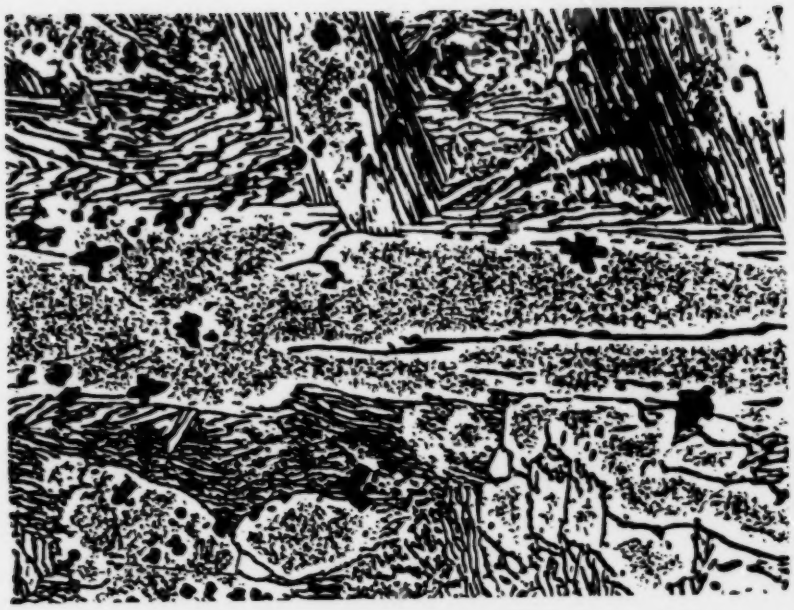


(b) fusion zone (neg 10478)

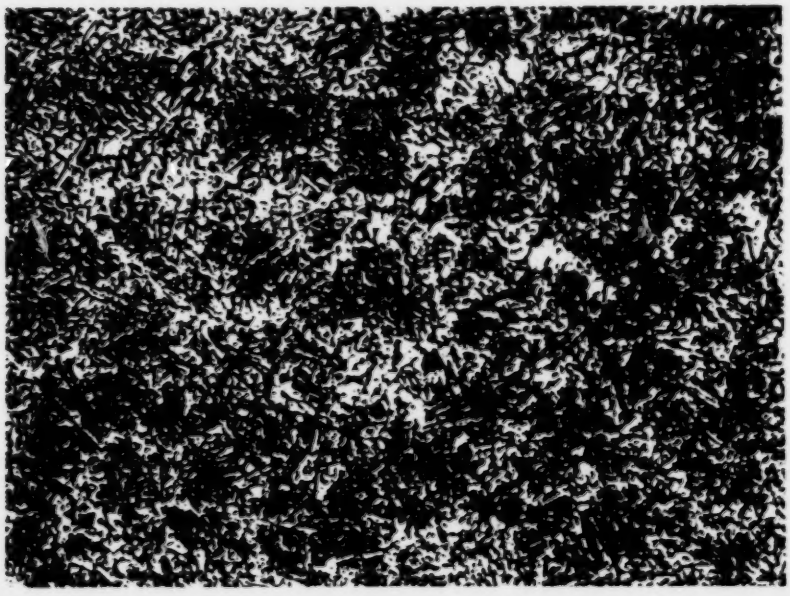


(c) HAZ (neg 10473)

Fig. 4. Scanning electron micrographs of the weld-repaired area. Ampcotrode 46 filler wire. Alcoholic ferric chloride etch.

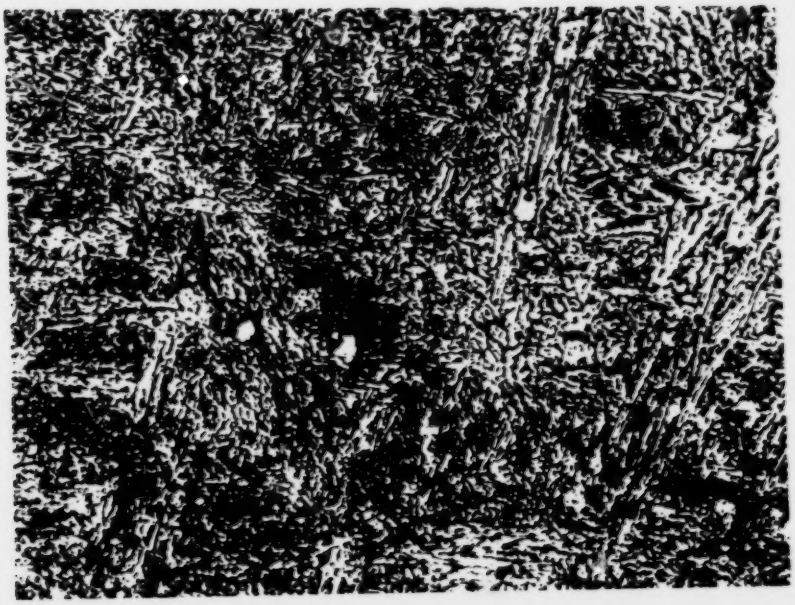


(a) Base metal (neg 10528)



(b) Busion zone (neg 10527)

Fig. 5. cont'd.

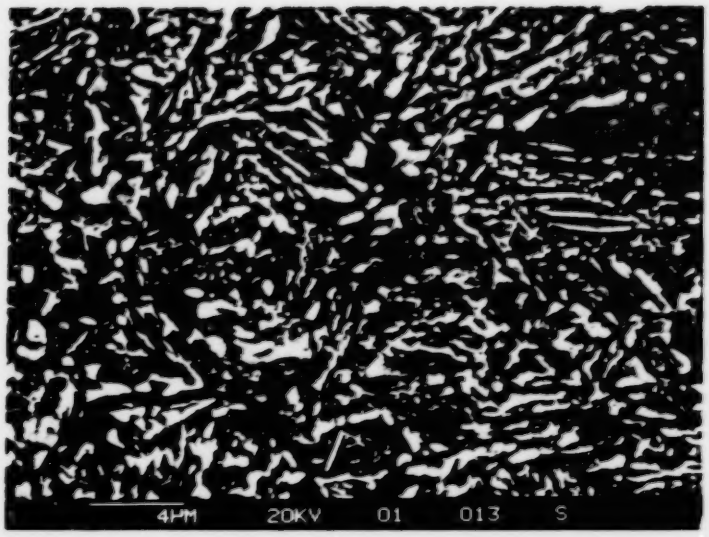


(c) HAZ (neg 10526)

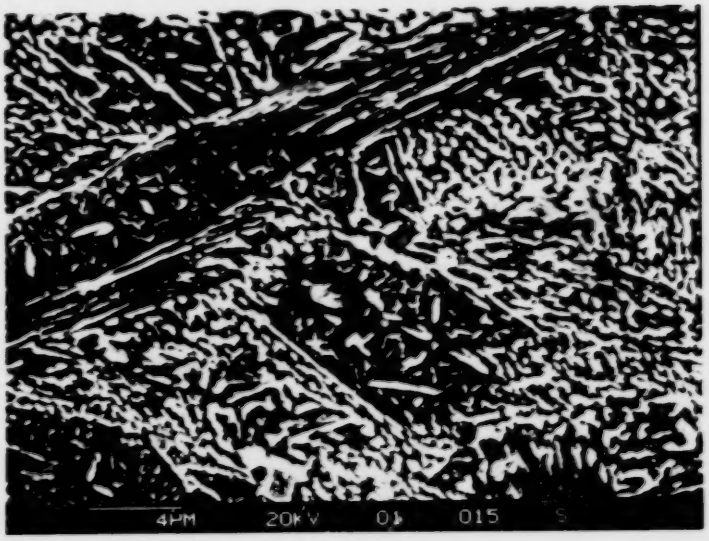
Fig. 5. Optical micrographs of the weld-repaired area after the post-weld heat treatment for 6 h at 700°C. Ampcotrode 46 filler wire. Alcoholic ferric chloride etch.

(a) Base metal (neg 10479)

Fig. 6. cont'd.



(b) Fusion Zone (neg 10480)



(c) HAZ (neg 10474)

Fig. 6. Scanning electron micrographs of the weld-repaired area after post-weld heat treatment for 6 h at 700°C. Ampcotrode 46 filler wire. Alcoholic ferric chloride etch.